

University of Edinburgh.

THESES PRIZE COMPETITION.

Thesis by *L. R. H. P. Marshall*

It is requested that this Thesis should be read and circulated in the following order, and thereafter returned to the Office of the Medical Faculty :—

	WHEN FORWARDED.
PROFESSOR <i>Wyllie</i>	<i>7th June 1909</i>
" <i>Hunter Stewart</i>	<i>10th</i>
" <i>Caird</i>	<i>11th</i>
" <i>Greenfield</i>	<i>18th</i>
" <i>Fraser</i>	<i>24th</i>

N.B.—When forwarding this Thesis to next Member of Committee, it should, if possible, be passed through the Office. When more convenient to hand direct to next reader, a Post Card should be sent to the Office giving date when Thesis forwarded.

.61748

P A R A C E N T E S I S S P I N A L I S .

Thesis for Degree of M.D.

by

Legh Richmond Peter Marshall,

M.B., Ch.B.



PARACENTESIS SPINALIS.

The subject is considered under the following headings:

	Page
Introduction	2
History	3
General Considerations	4
Special Anatomy	8
Technique	13
Complications	26
Meningeal Effusion	35
Diagnostic Value	38
Therapeutic Value	65
Conclusion	68
References	68

Introduction

Since Quinke published his first paper on lumbar puncture in 1891 a considerable amount of attention has been devoted to the subject, and, during the last five years, a great deal of literature bearing on the matter has been produced. The greater part of the experimental work has been conducted on the Continent; though it does not appear to have become a recognised practice among the rank and file of practitioners, either there, or in this country where it is slowly gaining popularity, but with commendable caution, for the range of its utility and its limitations have still to be decided.

History

The honour of being the first to attempt "local medication of the cord" appears to belong to the American physician Leonard Corning, who described a method of producing spinal anaesthesia in a memoir appearing in 1885 in the New York Medical Journal. He commenced by employing extradural injections, but extended his researches, until, in 1894, he was convinced of the value of penetrating within the meningeal coverings of the cord. Corning does not appear to have attracted any disciples in this line of research, and the methodical study of the subject is generally dated back to the time when Quincke first introduced it. A few years later results of experimental work were published by Chipault, Sicard and others, and in 1889 Bier came into the field with the results of operations performed on patients suffering from surgical affections of the lower limbs, in whom the spinal cord had been cocainised locally. The same year Tuffier commenced employing lumbar puncture and spinal anaesthesia. Since that time the communications and number of workers on the subject have been rapidly increasing.

General Considerations.

While by nature paracentesis spinalis is a somewhat alarming operation to perform, the risks are very small when carried out with proper attention to detail; and there is no reason why it should not rank along with paracentesis of other body cavities in the diagnostic armature of the physician. The technique is of so much importance and so much clinical information can be learnt at the time of the operation from the behaviour and the character of the fluid, that considerable attention will be paid to this aspect of the matter before discussing the process in relation to various pathological conditions.

Spinal puncture is made in the interlaminar spaces which separate the vertebrae from one another behind. These spaces, looking at both sides together, are lozenge shape and of greatest magnitude at the centre between the spinous processes. In the lumbar region the various structures which have to be traversed are the following: Skin, superficial fascia; posterior lamella of lumbar fascia; the erector spinae muscle; the ligamentum subflavum, composed of yellow elastic tissue; the peri-dural space

separating the walls of the spinal canal and its periosteum from the dura mater and filled by loose fat and areolar tissue, and by the intraspinal plexus of veins; the tough fibrous dura mater; the subdural space; the delicate arachnoidea spinalis; the subarachnoid space, which contains the cerebro-spinal fluid. The greatest point of resistance to the needle is as it pierces the ligamenta subflava. After penetrating these it is in the spinal canal and the point is felt to be free. Sometimes the resistance of the dura mater can also be perceived. The interlaminar space between the fourth and fifth lumbar vertebræ is the one commonly chosen for spinal puncture. With the aid of the highest points of the iliac ^{as} crests [^] landmarks this space is comparatively easy to define and it is to be recommended for general use. Theoretically the subarachnoid space may be punctured anywhere between the second lumbar vertebra and the base of the sacrum without fear of damaging the cord, except in young children. It is well to avoid the second interspace, except in special circumstances, for fear of possible abnormalities in the termination of the cord; but the third interspace is as safe as the fourth, and it may be used where unsatisfactory results are

obtained at the fourth interspace, or where successive punctures at short intervals are being made, thus making a fresh site desirable. Paracentesis in the dorsal region has been recorded without any untoward result, and, as long as it is possible to be certain of a distension of the sub-arachnoid space with fluid, puncture may be made at any level by a careful operator. But the risks are considerable, and the only indication for such a proceeding is in very critical cases, when no fluid can be obtained from the lumbar region. I have found it possible to obtain fluid by puncture of the cervical region post mortem, when none was obtained in the lumbar region. The spaces between the laminae are greatest in the lumbar region and smallest in the mid-dorsal region; the operation increases in difficulty therefore in the dorsal region, the obliquity of the spinous processes adding to the difficulty. Many prefer the space between the fifth lumbar vertebra and the first piece of the sacrum as practised and recommended by Chipault of Paris. It is said to be more simple and less dangerous, but I have not found this site offer any advantages. Where it is desired to introduce therapeutic agents into the spinal canal but external to the dura mater, puncture

may be made in the triangular deficiency at the apex of the sacrum, on a level with the sacro-coccygeal joint. A needle can be inserted here in the middle line by directing it obliquely from below upwards and from behind forwards for a distance of 2 to 5 centimetres.

Special Anatomy.

Before proceeding further certain anatomical features of the vertebral column and spinal cord may be recalled to mind with advantage. The spine is divided into 7 cervical, 12 dorsal and 5 lumbar vertebrae, the sacrum and coccyx. It is convex anteriorly from the first cervical to the second dorsal and from the twelfth dorsal to the first sacral; concave anteriorly from the second to twelfth dorsal and from the first sacral to the tip of the coccyx. There is also usually a slight lateral curve, convex to the right, in the dorsal region. The spinous processes are easily palpable, except those of the third, fourth and fifth cervical vertebrae. The cervical spines project horizontally backwards, the dorsal are long and oblique, the lumbar are thick and end in a rough vertical border. A line uniting the highest points of the two iliac crests intersects the fourth lumbar spine in the middle line, and a line joining the posterior superior iliac spines intersects the spine of the second sacral vertebra. Down the centre of the back is the vertebral groove, which is broad and shallow in the cervical region (nuchal furrow), narrow and deep in the dorsal region, narrow and rather

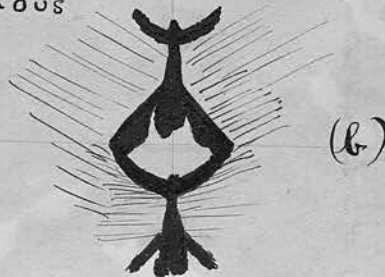
shallow in the lumbar region. The vertebral canal is bounded by the body of the vertebrae anteriorly, and by the neural arches, made up of pedicles and laminae, posteriorly. The bodies are bound together by the anterior and posterior common ligaments of the spine and by the intervening joints; the neural arches by the ligmenta subflava, each ligament being attached to the inferior margin and anterior surface of the lamina of the vertebra above and to the superior margin and posterior surface of the lamina of the vertebra below, and by the inter-spinous ligaments, intertransverse ligaments, and the articulations between the articular processes. The canal is broad and triangular in the cervical region, small and circular in the dorsal, triangular and intermediate in size in the lumbar, becoming smaller and flattened from before backwards towards the middle of the sacrum. There is a deficiency in the posterior wall at the lower end of the sacrum. The presence of a plexus of veins superficial to the neural arches and deep to the muscles accounts for free venous bleeding, which takes place occasionally from the puncture wound.

The spinal cord is 43 to 45 cm. long and extends from the foramen magnum to the lower border of the body of the first or the upper border of the body of the second lumbar vertebra. The exact position of the lower end varies slightly according to the curvature of the vertebral column. At birth the cord reaches to about the third lumbar vertebra, and in a three month fetus occupies the whole length of the vertebral canal. The lower end of the cord tapers to a point (conus medullaris) and ends in the filum terminale. The ^{enlargement} cervical [^] extends from the upper limit of the cord to the body of the first and second dorsal vertebra, and is largest opposite the fifth or sixth cervical vertebra. The lumbar enlargement begins at the tenth dorsal vertebra, and is largest opposite the twelfth. The cord is enveloped in a sheath of membranes larger and longer than itself. The dura mater and arachnoidea spinalis extend to the level of the second or third section of the sacrum, where they end by blending with the filum terminale. The pia mater is a tough membrane which closely invests the cord, and the blood vessels of the cord lie between its two layers. Between the arachnoid and the pia mater is the wide subarachnoid space

containing the cerebro-spinal fluid. The dura-mater forms an even wider and looser covering to the cord and cauda equina in the cervical and lumbar regions than elsewhere. The membrane has also only a flexible attachment to the walls of the spinal canal from which it is separated by a good deal of loose areolar tissue, fat and venous plexuses. The vessels of the spinal cord are numerous but small, and call for no special mention here. The intraspinal vessels on the other hand are closely concerned in the subject under consideration. A minute artery enters the spinal canal through each intervertebral foramen and supplies the bones, periosteum, ligaments, spinal cord and membranes. The intraspinal veins are arranged in an anterior and a posterior plexus. The anterior plexus is composed of two main longitudinal vessels situated one on either side of the posterior common ligament of the vertebral bodies, and connected with each other by numerous transverse branches. The posterior plexus has similarly two main vessels united by transverse branches placed along the deep aspect of the neural arches and ligamenta subflava. It communicates with

the occipital sinus above and has numerous communications through the ligamenta subflava with the dorsal spinal venous plexus.

Diagrammatic view
of
Interlaminar
Space seen from behind
(a) With spines removed
(b) Overhung by spinous
processes.



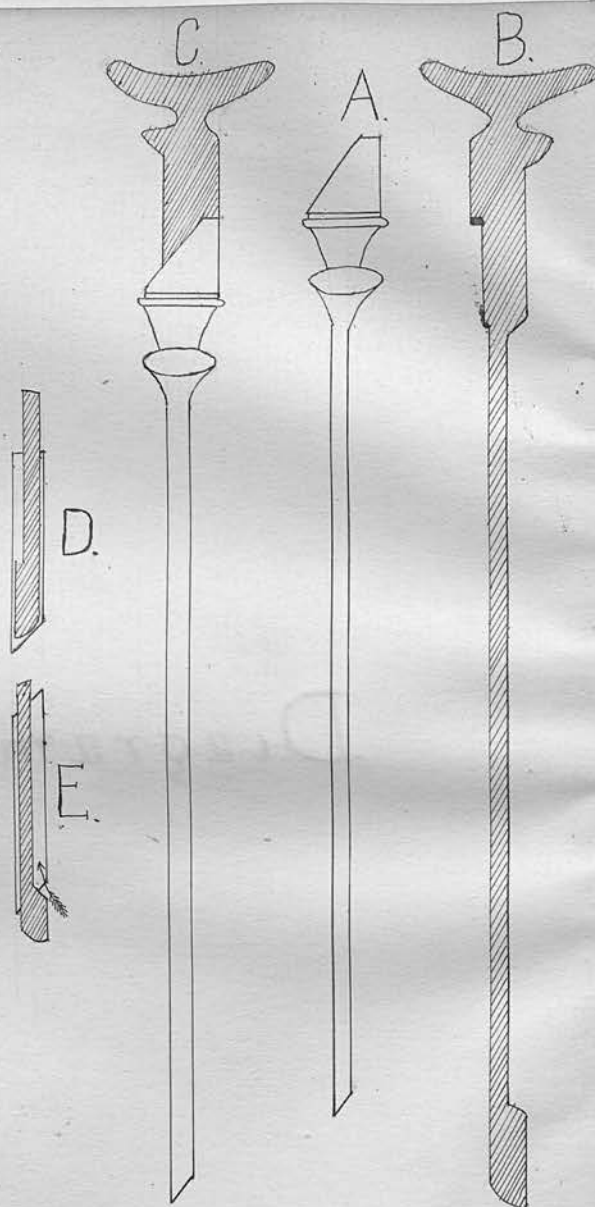
Technique.

The instruments required are few and simple and consist of a suitable needle, and sterile tubes to collect the fluid. Various patterns of needles are finding their way on to the market. The one I have been using with very satisfactory results for some time past, and which was made to my design by Messrs. Gardner & Son, Edinburgh, will be described here. The most essential consideration in any needle for spinal puncture is that the piercing end of the needle should have a short bevelled point. Most of the undesirable results I obtained at first were due to using unsuitable needles with long oblique points, like large exploring needles. To obtain the fluid with these it was often necessary to force them right up against the anterior wall of the canal, even then without success sometimes, owing to the whole of the orifice of the needle not having penetrated within the membranes. Also these long points are very apt to become bent on meeting any resistant body, thus causing unnecessary damage to the tissues and making even the process of extraction a painful one. This detail is becoming generally recognised

now since lumbar anaesthesia has come more into vogue, and since Tuffier's and Bier's needles have commanded attention. The diameter of the bore of the needle may be left within limits to individual preference. For infants, where the cerebro-spinal fluid is being drawn off simply to relieve pressure, a fine exploring needle with a short bevelled point and a wire stylette will be found to answer quite well. But in all cases where there is possibility of a purulent meningitis a comparatively large bore is essential to permit of the passage of the pus through the needle. In cases of epidemic cerebro-spinal meningitis this pus is occasionally very thick and flaky. A precaution upon which I lay particular stress, but which is not very generally practised, is that the needle should be provided with a stylet, preferably closely fitting and bevelled at one end to fit the bevelled end of the needle. The advantages of such a stylet are that it prevents the needle becoming blocked by muscle or other tissue during insertion, or by blood clot, and it affords facilities for determining that the passage of the needle is free, if for any reason no fluid is obtained or the fluid ceases to flow. Added to this extraneous cells

do not collect in the needle during its passage through the tissues, subsequently to become mingled with the cerebro-spinal fluid. The reality of this accident is proved by the following example. I performed lumbar puncture in a woman who had been admitted to hospital for typhoid fever, but the case was a very obscure one with a rapidly deepening coma, and the accuracy of the diagnosis was doubtful. In the fluid collected I was puzzled to find numerous globular bodies like fat, which they proved to be on appropriate staining. The patient had a great deal of subcutaneous fat in a semi-fluid condition and the question presented itself whether the fat was an extraneous contamination or actually belonged to the cerebro-spinal fluid. Post mortem no unusual cells were found in the fluid, and the globules of fat must have found their way into the needle during transit through the subcutaneous adipose tissue. This was before I had adopted my present form of needle. By protruding the end of the stylet beyond the point of the needle it is possible also to free the orifice of nerve or other tissue which may be lying up against and occluding the opening - an accident which sometimes happens.

Diagram



PARACENTESIS NEEDLE.

- A. Needle (side view)
 - B. Stylet.
 - C. Stylet in first position within needle
(In B stylet has been rotated so as to
occupy second position in relation to
the needle)
- Relation of end of stylet to needle is shown at
- D. in first position.
 - E. in second position (Arrow shows
opening for fluid.)

The paracentesis needle mentioned above is designed with special reference to these requirements (see diagram). The needle is 8 centimetres long, and has a diameter of 1.5 millimetre, a useful dimension for all ordinary purposes. The point is ground down to a short bevel. The socket at the head of the needle fits the ordinary serum syringes, and has a bevelled upper surface, facing in the opposite direction to the bevel of the lower end, so as to permit of the extension of the end of the stylet beyond the point of the needle. The bevel of the stylet is slightly shorter than that of the needle so as to leave the point and cutting edge of the needle free, while at the same time completely blocking the orifice of the needle, and allowing the end of the stylet to be rounded off. The upper end of the stylet is fitted with a hilt which has a flat thumb rest superiorly, and which is bevelled on its inferior surface to fit the superior bevelled surface of the hilt of the needle. The lower edge of this inferior surface is fitted with a pin which fits into notches on the surface of the needle hilt so as to prevent inadvertent rotation of the stylet. The shaft of the stylet is ground flat on the longer side to within a distance of the end

corresponding to the distance from the upper to the lower level of the bevel on the hilt. By this device the orifice at the end of the needle is completely blocked by the well fitting lower end of the stylet when the latter is at its first position, but when the stylet is turned through half a circle and driven home a narrow passage is opened up which allows fluid to escape drop by drop. At the same time nerve filaments or other occluding tissues are held away from the orifice of the needle while the fluid is escaping and so extra facilities are provided for determining if the dura mater has really been pierced or not, and also the anterior wall of the canal can be gently palpated with the blunt protruded end of the stylet without fear of serious damage. Another advantage is that the fluid is prevented escaping too fast - a matter of importance, as will be shown later - while the stylet can be withdrawn altogether for a second to enable one to estimate any increase of pressure of the cerebro-spinal fluid which there may be. Should no fluid escape the stylet should be withdrawn after protruding it to its full extent, and, in cases where there is thick pus in the lower part of the subarachnoid space, a perceptible amount

of this can be drawn out on the shelf at the foot of the flattened side of the stylet. The needle will then be left free for the application of a syringe. Another minor advantage is that when the stylet is protruding beyond the end of the needle in the second position, it forms a protection and support to the point; a convenience to take advantage of when sterilising the instrument. Both the needle and stylet are made of steel, a material which I find answers quite satisfactorily and which is much less costly than the platinum with iridium point usually advocated. Of course these more valuable metals wear longer and give a finer finish to the instrument and are advised where cost is a minor consideration. I have given trial to fine trocars and canulae, but they require more skill in use and there is greater risk of doing unnecessary damage with them. When used the point of the trocar must be a short one.

The preparation required for performing spinal puncture is simple. Ordinary aseptic precautions must be taken and can be allowed to vary according to individual preference & custom. The needle & stylet must of course be boiled. Sterile

tubes to collect the fluid are necessary if any bacteriological examination is contemplated. The skin of the patient may be prepared by ordinary cleansing with soap and water followed by alcohol or ether, or even better by corrosive sublimate alcohol. The operator's hands should be scrupulously clean. The neighbourhood of the area for operation is shielded by sterile towels with advantage.

As regards the actual performance of the operation the greatest secret to a quick and happy result is the position of the patient. The lumbar spine must be bent forward to the greatest possible extent so as to open up the interlaminal spaces to their widest limit. This may be done by the patient sitting on the end of a bed or table and bending well forward; or by the patient lying on one or other side in a sitting attitude, with the thighs well flexed on the abdomen and the knees drawn up towards the chin, and with the shoulders stooping to meet them. The surface on which the patient is sitting or lying should be as flat and rigid as possible to prevent the vertebral column being thrown into curves and bends which may distort or obliterate

the desired space and lead to considerable difficulty. The buttocks should be pulled conveniently over the side of the bed to permit of easily collecting the fluid dropping from the needle. With young children and delirious adults the greatest difficulty is often found in holding them still in this position, and the skill of assistants, acquired by experience, will often save an unseemly struggle or the necessity of administering a general anaesthetic. Only those who have tried have any conception of the difficulty of holding still, in a fixed position, a helpless looking child with its marvelous and inexhaustible power of wriggling, or a powerful man who is robbed of his mental control. Personally I think it preferable to give a general anaesthetic in all such cases, any disadvantages attaching to the anaesthetic being of less importance than those attendant on violent and prolonged struggling. A custom in some quarters is to bend children over a pile of pillows. I have tried the position, but did not form a favourable opinion of it. The sitting position is used chiefly preparatory to spinal anaesthesia, and the interlaminar space to left or right of

the spine may be chosen; but with the patient on his side the spaces corresponding to the side on which he is lying, as being on the lower level, are recommended.

The patient now being in a good position the next thing is to define the spinal processes and the level at which puncture is to be made. In infants, thin children and adults, no difficulty is experienced in this, but with muscular or fat people the difficulty may be very great. Where a thick layer of subcutaneous fat is the cause of difficulty firm pressure maintained by the thumb for a minute or two will often displace locally some of the soft fat and enable the bony landmarks to be defined. It has been mentioned already that a line joining the highest points of the iliac crests crosses the 4th lumbar spine in the middle line. The spinal eminences above and below this level are defined, or, if there is uncertainty as to what is felt, it is a help to trace down the spines from a higher level by touch. The interspinous spaces are then located by the left thumb or forefinger, and, the site of election being determined, the locating digit is used as a guide to the point of the needle. The needle (if the special one described is being used) is held between the first and second fingers of the right

hand with the thumb resting on the disc of the stylet to steady the instrument and to push it home to its destination. The point of the needle is placed against the skin over the space which has just been defined, at about half to one centimetre to the side of the mid-spinal line, in adults, while in young children actually the middle line will be found to answer well, and the patient, if old enough and conscious, is warned that his back is going to be pricked and admonished to try and keep quite still. The point is made to penetrate the skin with a rapid movement and the needle is then steadily pushed in a forward direction and with a very slight upward and inward inclination through the interlaminar space. The needle will require to be introduced for about 5 or 6 centimetres in the adult and about 3 centimetres in the young child. On entering the space the point of the needle will be felt to be free and the stylet should be revolved to its second position, when, if the membranes have been pierced, fluid should commence to drop out. If no fluid is obtained withdraw the stylet a little and rotate the needle. This simple manoeuvre is often sufficient to determine a perforation of the dura mater, which before was only indented by the

needle point. The stylet is then replaced in its second position and the fluid allowed to escape. The stylet can be withdrawn completely for a moment to obtain an indication of the pressure under which the fluid is contained in the canal, if the pressure is normal or low and no block to the needle occurs, it need not be reinserted. Should no fluid be obtained, or only a drop or two, and some doubt is felt as to the needle having entered the canal, the stylet should be advanced to its second position and the needle may then be pushed gently onwards until the anterior wall of the canal can be palpated with the end of the stylet. On withdrawing the needle the puncture should be sealed immediately with collodion. Local anaesthetisation of the skin is frequently taught and practised, but freezing and other methods are quite as painful, if not more so, than the stab of a sharp needle, and they increase the difficulty of puncturing exactly in the right spot. In some cases in which I had given no warning the fluid was issuing forth before the patient knew the needle was in.

Accounts vary a little as to the direction in which the needle should be pointed and the distance from the middle line and below the level

of the spinous process at which it should start its journey. The truth of the matter is that there is a very small latitude possible and each operator must acquire for himself an accuracy which can only be learnt by practice.

The above details will, if studiously attended to, secure success in nine cases out of ten, even to the novice. Slight differences in the position of the patient, and possibly of the contour of the bony points, will be sufficient to require sometimes a slight deviation from the direction usually given to the needle. The sitting position is the one in which it is possible to obtain most uniform results, and the needle can usually be inserted in a horizontal direction. But this position while practicable for spinal anaesthesia in surgical conditions is often impracticable or undesirable in medical conditions.

When serum or other fluid is to be injected by the spinal route there are certain practical points worthy of attention. The fluid should be warmed so as to reach its destination at about body temperature. This will lessen any tendency to shock and not arouse unnecessary sensations. A quantity of cerebro-spinal fluid bearing some

relation to the quantity of serum to be injected should be withdrawn if possible. Should there be a great excess of the cerebro-spinal fluid under high pressure, then the amount withdrawn must depend on the indications for that particular case. The ingoing fluid must be injected slowly. Individual cases vary greatly in the ease with which injections are admitted. Some begin to cry out about their legs at the very start and then the injection has to be done with extreme slowness. The patient's sensations are the guide to the rate of injection admissible. It is to the mental comfort of the operator that the patient attributes the pain in his legs to an undue energy on the part of the nurse controlling the position of these limbs, and not to the manipulations of the physician.

Complications.

Certain difficulties and complications happen now and then when performing spinal puncture. Obstreperousness on part of the patient has already been dealt with and can always be overcome, if need be, by a general anaesthetic. Anatomical faults or conditions may lead to trouble. Curvature of the spine needs only to be mentioned. In a case of osteitis deformans where the trunk had become shortened and collapsed I failed to enter the canal. Great muscularity or excessive obesity are the two most common causes of difficulty under this heading, and in such cases it will be found that the full length of the 8 centimetre needle will be required. In these cases it is often barely possible to feel the spinous processes, much less the interspinous spaces, and the best plan will be found to keep the left thumb on the edge of the spine and to estimate by sight the point at which the needle should be inserted. Or the plan recommended by Juvara may be tried. He depresses the tissues between two spines with an instrument resembling a paper-knife, and on releasing the pressure a mark is left on the skin indicating very accurately the level of

the interlaminal space. It is necessary to remember that the skin does not bear a constant relation to the underlying parts and the slightest movement on the part of the patient may alter a previously existing relationship. Thus a mark on the skin or a point indicated by the guiding finger may both become quite useless suddenly. Some patients cringe and hollow their back directly they are touched and so undo all the good of the position into which they have been so carefully brought. With patient and reassuring conversation their nervousness can be largely overcome. Occasionally the needle will run up against the bony wall just external to the ligamenta subflava or can be felt grazing along the walls of the bony channel: a slight alteration of the inclination of the needle will often rectify this.

Once within the canal the operator may be disappointed to obtain no fluid. The ordinary manipulations required under such circumstances have already been described. But there are a certain number of cases in which it is impossible to obtain fluid, and others in which no fluid may be obtained on the first, second or third occasions, and yet ^{be} obtained subsequently. In the same

way, if much fluid has been withdrawn on previous occasions, no fluid may be obtained on one or more subsequent occasions. The reason for no fluid being obtained is at present theoretical. Often failure can be explained by the needle becoming blocked by tissue or blood clot, or by the orifice becoming occluded by nerve or other tissue compressed against it. These causes can be overcome by a suitable needle such as that already described, but even then occasionally cases with no fluid will be encountered. In some cases there is reason to believe that local adhesions have taken place, especially where there has been a meningitis; or an obstruction may exist between the ventricles and subarachnoid space; or again there may be some slight abnormality of the membranous canal. In all cases a second or third puncture should be attempted through another space. A possibility to bear in mind is that the end of the needle may be buried in the septum posticum which connects the posterior aspect of the pia mater with the arachnoid mater. Changing the direction of the needle as far as may be possible should free the orifice from this entanglement. There is no doubt that fluid may collect in one part of the system of cerebro-spinal cavities and be practically

absent from another part, whether due to local activity of secretion or other causes, so leading to a variable pressure in different sections of the system; and it must be remembered that the fluid travels but slowly from one end to the other of the system. This is proved by the patient slowness which needs to be exercised when injecting fluids into the subarachnoid space. Rapid injection causes local compression of the nerve elements, with pain referred to their area of distribution. The subarachnoid space of the brain is broken up by filaments and trabeculae which form an extremely delicate meshwork; and the corresponding space of the cord is divided into three more or less distinct compartments by the ligamenta denticulata situated laterally, and by the mesial septum posticum already mentioned. Of late, therefore, when dealing with cases where no excessive increase of pressure of a chronic nature exists, or where no emergency puncture without delay is called for, I have been in the habit of raising the head of the bed on blocks for two or three hours before performing lumbar puncture, remembering to remove the blocks as soon as the operation is completed. For the same reason

when injecting serums and other medicaments I raise the foot of the bed on blocks and leave it raised thus for from one to twelve hours. Of course this practice does not apply to injection of anaesthetics where it is desired to confine the action of the drug to a localised area. Rarely one drop, or perhaps three or four, are obtained on puncture, and then the channel seems to be run quite dry. It is conceivable that the subdural space may at times be the site of a slight effusion, and that a localised distension of this space may be entered. Curshman noticed that the application of cold to the skin increased the pressure of the cerebro-spinal fluid, and he successfully applied this knowledge to a case of epidemic cerebro-spinal meningitis in a child in whom the fluid was too thick to flow through the needle, by freezing the skin of the thighs with ethyl chloride. I have made the experiment frequently in hopeful expectation, but with disappointing results. It accelerated the flow of fluid slightly in some cases - all of them cases of epidemic cerebro-spinal meningitis; but, for some unexplained reason, it has failed entirely so far in all other conditions.

It is not uncommon for a few drops of blood to precede the cerebro-spinal fluid and for the first few drops of the latter to be mixed with blood. The fluid soon comes quite clear however and the tube collecting the blood stained fluid should be discarded and a second tube, which should always be at hand, substituted, otherwise the subsequent examination of the fluid will be misleading. This blood is due to puncturing the posterior intraspinal venous plexus and is not of any consequence. Should the needle be driven up against the anterior wall of the canal the anterior intraspinal venous plexus is likely to be injured and is an accident of much greater importance. The blood continues to escape and to contaminate the cerebro-spinal fluid which is being collected, and also leads to the formation of considerable blood clot in the canal. On two occasions I have had copious haemorrhage occurring at the end of the proceeding instead of at the beginning. The cerebro-spinal fluid had been coming quite clear and then suddenly became blood stained, to be rapidly followed by what looked like pure blood. The only course open to one in such a case is to withdraw the needle. Both the cases mentioned ~~where~~ in the chronic stage of epidemic cerebro-spinal meningitis,

in whom suppuration had ceased and in whom the fluid was under high pressure and quite clear, except for a filamentous clot on standing. No symptoms attributable to the bleeding occurred in either case, and they both pursued the uneventful downward path common to the disease. One of the cases was punctured in the lumbar region a few weeks later and a large quantity of yellow fluid, probably a mixture of cerebro-spinal fluid and blood serum, was drawn off, with temporary improvement of the symptoms. Useful lessons may be gathered from these cases. The bleeding no doubt proceeded from vessels of the cord that had been corroded by the suppurative processes which had previously existed, and that ruptured when the pressure of the cerebro-spinal fluid had been relieved. A Brittleness of the vessels due to old age or constitutional disease may lead to a similar contretemps, and warn one to exercise increased caution when relieving pressure in the spinal canal. The cerebro-spinal fluid is sometimes yellow in colour after suppurative meningitis apart from such an accident to explain it, but the process is probably no different. Note that this yellow colouration is not perceptible by ordinary artificial light and the fluid should always be kept for examination by daylight.

When serum is being injected into the spine I have witnessed a tumour gradually rising over the site of injection to the accompaniment of the patient's subdued articulations. This implies either that the needle had not penetrated the meningitis or that it had been allowed to slip out partially and that the serum was escaping into the surrounding tissues. Possibly also a certain amount of the injection may force a way out along the outside of the needle.

Any other complications which may happen are in the nature of sequelae and can almost always, if not always, be traced to extracting too large a quantity of the fluid at one time. The patient may even cry out about his head at the time of the operation if an excessive amount of the fluid is withdrawn, or if it is allowed to escape too rapidly. For this reason it is wise to control the rate of the flow when the fluid is under high pressure by some such method as provided for by my needle. In less aggravated cases the pain in the head, which is very intense, and, it may be, nausea and vomiting also, do not occur till some six hours or more afterwards. The symptoms may last for an hour or two to some days. Where the cerebro-spinal fluid is not under increased pressure

not more than 3 to 7 cubic centimetres should be withdrawn at one time. I have never seen any after results following on the extraction of this quantity. Where the pressure is increased the amount withdrawn must be regulated according to the degree of pressure and can only be learnt by experience. A very fair guide is to stop as soon as the fluid escapes at about the normal rate, or very slightly below the normal pressure. That such severe symptoms may follow extraction of the meningeal fluid shows that the process has its indirect dangers. Continental observers have reported death as a result of lumbar puncture. Williamson quotes Gumparect's record of fifteen cases of immediate death. Rons records 14 deaths in which 25 to 90 cc. fluid had been withdrawn. To lessen the risks of such a disastrous result the patient should be kept strictly in bed for the 24 hours following the operation.

Meningeal Effusion.

The diagnostic value of paracentesis spinalis rests upon the character - physical, chemical and microscopical - of the fluid obtained. Normal cerebro-spinal fluid is colourless, clear and watery, of low specific gravity (1.004 to 1.007), and contains only a trace of coagulable proteid. These properties, and the presence of a reducing substance, differentiate it from all other serous fluids. The fluid of hydatids agrees, perhaps, more closely than any other effusion with the meningeal fluid, except in its special microscopical features. The total quantity of the cerebro-spinal fluid in health is, according to Mott, 120 to 150 cc. The proteid consists of serum globulin with a trace of albumose, and, according to Renon and Tixier, generally varies in amount directly with the number of cellular elements present in the fluid. The albumen only amounts to from 0.2 to 0.5 per cent. In pathological conditions it may be increased up to from 2 to 8 per cent. The number of cells is from 0 to 2 in a c.mm. of the normal fluid. Over 5 to a c.mm. is indicative of a pathological process in the meninges. (Joffroy and Mercier).

The pressure under which the fluid is found

is of great interest and importance. The pressure in the subarachnoid space and in the ventricles should be the same. In lateral decubitus the normal pressure is 120 to 180 mm. distilled water according to Kronig, 125 mm. according to Quincke. Authorities vary as to the height pressure may reach in disease. Quincke gives 700 as the highest and Schonborn says up to 1000 mm. water. For ordinary clinical purposes it is sufficient to know if the fluid is under low, normal, high or excessive pressure, and this is not difficult to estimate by the rate at which the fluid escapes from the needle, once the normal rate for a fixed size of needle has become familiar to the eye. Sometimes directly the needle penetrates the membranes the tension is so great that the fluid squirts out in a strong jet. Allowance must be made for factors which alter the blood pressure, such as coughing, straining, or fright, for these also affect the pressure in the subarachnoid space.

The reducing substance found in the meningeal fluid is not sugar, and its estimation throws little light upon pathological conditions. But, with an advance of knowledge, it is probable that the estimation of the quantity present of another complex chemical body-Cholin, will be of

distinct service. Cholin is a ptomain in close structural relation to muscarin, but it is not nearly so toxic as this latter substance, though it may be decomposed into neurin which is a highly poisonous body. Cholin is said to be present normally in every cell, and it can be found in extremely minute quantity in normal cerebro-spinal fluid. It is liberated during life whenever nerve tissue is broken down in any considerable amount. It is derived from the lecithin of the nerve tissue, and may be found in increased amount in diseases associated with the destruction of brain tissue. An interesting fact in the chemistry of the meningeal fluid is that it usually contains a higher proportion of potassium relatively to sodium than other body fluids.

The freezing point on an average is -0.520 to -0.540 , and according to Fuch's and Rosenthal (quoted by Wells) it is lowered about the same in all diseases except in tubercular meningitis where it may be reduced to -0.430 .

Diagnostic Value.

In disease the meningeal fluid is often greatly altered macroscopically as well as microscopically, and the information to be gleaned from these alterations will now be shortly considered.

A Fibrin Clot may form in the fluid after standing for a time, like a cobweb to look at, in cases of tuberculous, syphilitic, and serous meningitis, and in sarcoma of the meninges.

Turbidity of the fluid indicates a meningitis. The fluid may be actually purulent.

Blood in the fluid may be due to accidental causes, such as were discussed when describing the technique of the operation. But it may also be mingled with the fluid in fracture of the skull or injuries to the spinal cord, in subarachnoid haemorrhage (spinal or cerebral), and in intraventricular haemorrhages. In these pathological conditions the fluid remains yellow even after centrifuging, and the fluid is equally tinged with blood from first to last; whereas in accidental admixture of blood the first drops of fluid are most tinged, and, after centrifuging, the blood corpuscles fall and the fluid becomes clear.

A Yellow colour of the cerebro-spinal fluid sometimes occurs in severe jaundice, and the fluid may also be faintly yellow, without being actually tinged with blood, in haemorrhage of the cerebrum or cerebral membranes. This is a guide in differential diagnosis from cerebral thrombosis in which the fluid is not tinged yellow.

The albumin is increased in purulent meningitis, in paresis and some chronic nervous diseases, and sometimes after intracranial haemorrhage. Pomeroy suggests, from a large number of observations which he has carried out, that the albumin content may act as an indicator when the cellular elements are absent. In a case of Nicol's which he quotes the albumin content was positive when the cellular content was negative at the first two punctures, and at the third puncture a lymphocytosis was found. This suggestion is one which deserves further investigation. The estimation of the albumin is carried out as follows:- Mix equal portions of cerebro-spinal fluid and saturated solution $Mg\ SO_4$, in the cold and filter. This removes the globulin. Now boil the filtrate and, if normal, it remains clear. The appearance of opalescence indicates the presence of serum albumin which is abnormal in

more than a faint trace.

The Cells in the cerebro-spinal fluid become much more numerous usually in those conditions in which there is an increase of albumin content. In the normal fluid, as already shown, they may be almost impossible to find, and consist of polymorphonuclear leucocytes with, perhaps, an occasional lymphocyte. There may be seen as well some structureless elements which are degenerated leucocytes. These are very common in acute meningitis. An increase of leucocytes is found in acute infective processes. A lymphocytosis may be caused by bacteria or chemical toxins, or simply by pressure due to increased secretion; and it is found in:

- (a) Some infectious diseases, e.g. typhoid, scarlatina, mumps, pneumonia, sepsis;
- (b) Herpes zoster, chorea, disseminated sclerosis (uncertain), heat stroke (uncertain);
- (c) Hydrocephalus, uraemia, tumour of brain (increase slight and probably due to pressure);
- (d) Trauma to skull or spinal column without a haemorrhagic discolouration of the fluid.
- (e) Syphilitic and tuberculous infections.

Lymphocytes also take the place of the leucocytes during recovery from acute meningitis. The cells

are said to be normal in alcoholism, in dementia praecox, and in psychoses non-syphilitic in origin, and this forms a useful factor in differential diagnosis. The fluid collected at one puncture is not always uniform throughout. The leucocytosis is sometimes greater in the fluid which escapes first, sometimes in that which escapes last, and, when this is observed it affords a possible clue to the site of a lesion. For this reason it is a useful custom to always collect a tapping in two or more receptacles.

The Bacteriology of the cerebro-spinal fluid is one of the surest and most valuable aids we have to diagnosis in pathological conditions affecting the meninges. The most valuable of all is the demonstration of the diplococcus intracellularis meningitidis of Weichselbaum. It can generally be found in large numbers in the pus or fibrin clot deposited by the fluid, both intra- and extra-cellular, and is easily stained by ordinary basic dyes. A growth on serum agar will confirm the diagnosis. It is described as gram-negative, but different strains have a variable action towards gram. Tubercle Bacilli can also be demonstrated in a large number of cases of tuberculous meningitis; some say in all cases, but

the search has often to be a prolonged one. The diplococcus pneumonia is a not uncommon find and gives rise to a recognised form of meningitis. Steptococcus and staphylococcus pyogenes are both found. Other organisms identified have been the B. influenza, B. pneumonia, B. typhi abdominalis, B. colicommunis, B. mallei, B. pestis, and other varieties in rare cases.

The Pressure is increased in intra-cranial tumours, in extravasation of blood into brain or membranes, and in a serous or purulent effusion into the ventricles of the brain or subarachnoid space.

The diagnostic value of tapping the spine will be made clearer by a consideration seriatim of the conditions in which it is of established use and some of those in which the position it is to take is not yet established.

Serous Meningitis.

In this interesting and important condition relief of the pressure by spinal puncture is a most valuable therapeutic procedure and almost startling in the rapidity with which it subdues the urgent symptoms. The condition is one which is easily confused with all manner of diseases, and many of the recoveries assigned to tuberculous and other forms of meningitis, and to cases of brain tumour, probably belong to this category. The acute form may easily be mistaken for epidemic cerebro-spinal meningitis. The fluid obtained by puncture is clear and free from bacteria. The pressure is greatly increased - up to 300 according to Quinke - and a large quantity of fluid can be safely withdrawn. The albumen content may be increased and a lymphocytosis found to be present. Fuchs reports finding urobilin in one case. Blumenthal believes the condition to be a serous meningitis caused by trauma following on a primary hydrocephalus, but it is not certain that the process is inflammatory.

Hydrocephalus.

The fluid within the ventricles of the brain is under high pressure and when the spinal subarachnoid sac is punctured the fluid issues with force. Pressure up to 660 mm. has been recorded, and Tobler reports the withdrawal of 650 c.cm. at one sitting. The colour of the fluid is clear, except for a slightly greenish tinge occasionally, and there is some increase of albumen.

Abscess of the Brain.

The meningeal fluid is under increased pressure. It is clear and free from bacteria and there is no excess of leucocytes, unless there is an extension of inflammation to the meninges when the character of the fluid may be altered. This affords a useful guide in differential diagnosis. Extreme caution must be observed in drawing off fluid by spinal puncture in suspected abscess, owing to the alteration of relative pressures and the danger, as Schönborn points out, of perforation taking place.

Cerebral Tumour.

The fluid is clear and under increased pressure. The albumen is increased and there is a lymphocytosis occasionally. Cholin is present.

Apoplexy.

Spinal puncture may give valuable information and be a useful means for relieving symptoms, but caution must be used for fear of setting up renewed haemorrhage. The fluid may be under increased pressure depending on the amount of haemorrhage, and also corresponding to the amount of rigidity according to Froin. Should the fluid be mixed with blood, as is frequently the case, blood must have escaped into the ventricles. The colour lessens with each puncture until it is finally colourless. Albumen and cholin are both increased. The lymphocytes depend on the pressure of blood.

Acute Meningitis.

Lumbar puncture is extremely useful for differential diagnosis. Bacteriological examination does not always succeed. A pneumococcal infection is the most common. The prognosis is bad in meningitis due to staphylococcal and streptococcal infection, also when the B. Coli Communis is present. A great deal has been written on influenzal meningitis - Kaupe mentions a case of Curschmann's in which the fluid was clear, the pressure normal, and the lymphocytes were many, but the leucocytes few; and a case of Hecht's in which the fluid was purulent and the pressure 150 mm. mercury.

The Bacillus of Typhoid is not often found and the spinal fluid has no constant character in this fever. When a purulent meningitis spreads from the ear the infection is often a mixed one. Where the symptoms and signs of a disease point to an acute meningitis but the spinal fluid is found to be clear and free from organisms and leucocytes, Gerhardt throws out the interesting suggestion that there may be a circumscribed purulent meningitis but not a diffuse one. The question requires further investigation. In epidemic cerebro-spinal

meningitis the lesion may be confined to a cerebral or a spinal area.

Epidemic Meningitis.

This disease has attracted many investigators of recent years and in no other condition has the value of lumbar puncture as a routine practice been so well recognised, especially since the value of injecting serums or antiseptic preparations into the spinal meninges has been realised. The specific diplococcus is most easily found during the early weeks of the disease, and, though no organisms may be found at the first puncture, subsequent examinations may be more fortunate. Is this a further instance of the fluid which is under high pressure escaping from below the infected area before the organisms have become widespread? In some cases no fluid can be obtained. The fluid may be under very high pressure, and up to 600 mm. water has been recorded. The fluid is sometimes clear at time of withdrawal, but is generally opalescent, grey, or quite thick - it may be too thick to pass through the needle. The albumen is increased, but the increase bears no relation to the severity of the attack. There is a leucocytosis at first and later a lymphocytosis. The freezing point is lowered

Tuberculous Meningitis

In this condition the fluid is under high pressure - up to 700 mm. water has been recorded. It is generally clear, but is sometimes opalescent, and on standing a fine core of fibrin often separates. This should always be looked for and the fibrin clot searched for the tubercle bacillus. The albumen is increased, but the increase is only of secondary importance. The presence of large mononuclear leucocytes is an important diagnostic feature. Many polymorphonuclear leucocytes point to a mixed infection. The freezing point is markedly lowered.

Syphilitic Meningitis

A lumbar puncture may afford useful help when there are meningitic symptoms without any definite indications of other disease. In syphilis the fluid is clear and under increased pressure. A lymphocytosis is a characteristic feature and there is often coagulation in the fluid. Pomeroy states that "a negative finding in a case with a syphilitic history is almost certain evidence that there is no involvement of the central nervous tissue, and in cases where brain syphilis is clinically to be diagnosed, a persistent negative lumbar puncture should make us look for some other etiologic factor." The lymphocytosis in brain syphilis is much more marked than in brain tumour, two conditions which often present very similar features.

Sarcomatous Meningitis

The fluid is said to be tinged brown or yellow, is of an inflammatory nature, and coagulates. Large cells similar to those of the growth have been found in the fluid, which also contains blood pigment, and a few erythrocytes and macrocytes.

General Paralysis of the Insane.

Almost all observers agree that a lymphocytosis in the meningeal fluid is a never failing accompaniment of a general paralysis. Jaffroy, Marie, Duflos and others say that a lymphocytosis is one of the earliest and most constant signs, and that it appears before the memory, eye and ataxic symptoms. Repeated punctures at intervals of about 10 days are necessary, as the first two or three may give negative results, but repeated failures contraindicate general paralysis. It should be mentioned that Raubitschek considers a lymphocytosis only of value as a positive indication, whereas Ballet thinks where it fails the disease will advance rapidly. A few polymorphs may also be found. The albumin is always increased, but observers disagree as to how far it corresponds with the cell content. Phosphate and cholin have also been found - The pressure is increased.

Tabes Dorsalis.

As in general paralysis of the insane so in tabes the lymphocytosis is often extreme when other symptoms are very slight. The albumin varies, cholin is present, and phosphates generally. The pressure is usually increased.

Friedreich's Ataxia.

Cytology gives negative results.

Multiple Sclerosis.

Lumbar puncture gives uncertain results.

Syringomyelia.

The cerebro-spinal fluid is said to have no increase of cells. Further investigation is required.

Poliomyelitis Anterior Acuta.

Pressure of the fluid is increased. Most authorities agree there is no increase of cells. Achard's and Raubitschek's observations do not quite agree with others in that one has found a lymphocytosis and the other a leucocytosis early

in the disease. The fluid is clear, but most variable results are recorded as to its bacteriological properties. Spinal puncture has a beneficial action

Herpes Zoster.

The lessons to be learnt from the cerebro-spinal fluid are still undetermined. There is generally a lymphocytosis but sometimes a leucocytosis.

Cyst of Dura Mater.

A case of Schmidt's is referred to by
Kaupe. The pressure was reduced and the fluid
clear.

Tetanus.

Not many observations have been carried out. A lymphocytosis has been found. In a case I had some opportunity of observing no fluid was obtained until after serum had been injected on three or four occasions.

Epilepsy.

The pressure of the fluid is increased, especially at the commencement of an attack. Skorzynski found that the pressure was maintained during the tonic stage, and after fluctuating, fell rapidly with cessation of the attack. Cells are increased in number according to some and decreased according to others. Cholin is present in true and in Jacksonian epilepsy. In a case of petit mal I failed to obtain any fluid on two occasions at six weeks interval. Curiously enough both these punctures were followed by an unusually long quiescent period - twenty-one days after the first time and twenty-five after the second without any seizure. There is an undoubted hysterical element about this patient who is still under observation, but also a true epileptic condition. Nearly three months after the second puncture I performed a third lumbar puncture one hour after I had seen her in one of her attacks. These were becoming rather more pronounced and prolonged. This time fluid was found and it issued forth under pressure. 14 cc. clear fluid were withdrawn, and, the pressure falling rather suddenly, some sterile normal

saline solution was injected to replace the excess. The patient had to be allowed to get up and go home unfortunately three hours after the operation. She felt no ill effects until another three hours had elapsed, when she was seized, she said, with severe headache and some soreness of the back. These soon passed off however. The fluid showed no abnormality. It was not examined for cholin. The cerebro-spinal fluid is said to be tinged with blood sometimes in grand mal. This probably indicates a congestive vascularity of the meninges.

Chorea. Tetany. Paralysis Agitans.

In these the fluid is normal usually. Chorea is stated to be relieved by lumbar puncture. A case of Chorea with increased pressure and another with lowered pressure have been recorded.

Hysteria and Neurasthenia.

In these conditions the fluid gives negative results on examination.

Exanthemata.

In typhoid fever polynuclear leucocytes are found and the specific organism.

In Parotitis there is a lymphocytosis during the height of the affection.

In Pertussis the pressure is raised and there is an increase of mononuclears.

Disease of the Kidneys.

In Nephritis the pressure is said to be below normal.

In Uraemia some record a lymphocytosis, others dispute it. The freezing point is raised. The pressure is sometimes raised and sometimes normal.

In Eclampsia the pressure is raised. One case with lowered pressure has been recorded.

Diseases of Metabolism and the
Intoxications.

In Diabetes the changes correspond to those in the urine.

In Jaundice the fluid is yellow but is free from bilirubin.

In Alcoholism there is no lymphocytosis and this is a useful fact in differentiating it from general paralysis of the insane and from tabes.

Insolation.

The reports on the cells found in the fluid in this condition are conflicting. The discrepancies depend possibly on differences in the severity of the cases observed. In severe cases it appears there may be a polynuclearcytosis at first and a lymphocytosis at a later stage. The albumen is abnormal. The pressure is raised.

Incontinence of Urine.

Babinski reports a case of instant cure, but does not claim more than psychic suggestion as the remedial agent.

Diseases of the Ear.

The spinal fluid can afford valuable diagnostic aid as to the existence of a meningitis following on ear trouble and also as to its nature.

Diseases of the Eye.

The observations recorded have been few, but in a case of syphilitic disease of the eye a lymphocytosis was found.

Conclusions as to the Diagnostic Value of
Spinal Puncture.

Note should always be made of the pressure under which the fluid is ejected. The naked eye character, the microscopical, chemical and bacteriological properties of the fluid should be determined.

Lumbar puncture should be repeated at intervals, especially when no fluid is obtained at first.

If a case be suspected to be one of meningitis but the cerebro-spinal fluid continues normal, the disease may be ruled out.

When the fluid gives constant negative results on examination syphilitic affections of the brain may be ruled out.

A Lymphocytosis is a constant and early sign in general paralysis of the insane and in tabes. The lymphocytosis in secondary and

tertiary syphilitic conditions is not so marked.

A Lymphocytosis is present in :

Tabes

General paralysis of the insane

Cerebro-spinal syphilis

Tubercular meningitis

Epidemic meningitis (late)

and is absent in :

Functional neurosis

Epilepsy

Multiple neuritis (?)

Alcoholism

Poliomyelitis

Syringo-myelia

When the fluid is clear and free from organisms in purulent otitis media and in brain abscess the prospects of operative treatment are more hopeful.

Therapeutic Value.

Paracentesis spinalis may be said to afford relief in all cases of intra-cranial pressure. In none is this better shown than in serous meningitis as has already been mentioned. It is the most rapidly efficacious remedy we have for relieving the distressing symptoms of convulsions.

in children. Where the convulsions are due to gastric or intestinal disorders, and other assignable causes, the usual steps to counteract these must of course be taken at the same time. I have cured children in a condition of status epilepticus by a single tapping, or at least until other remedies acted, and have subdued the contortions of a baby with general miliary tuberculosis by tappings repeated at a few hours interval so long as the fluid reaccumulated and the fontanelles bulged, without hastening the unavoidable end and yet soothing the harrowed feelings of the unhappy relatives. Boquel records a case of convulsions in the newly born which were cured by spinal puncture. Relief of the distressing symptoms in eclampsia may be obtained after the same manner. Chronic and untractable headaches can often be relieved, but great care must be taken not to withdraw too much fluid. For example migraine and severe headaches due to chronic Bright's disease, uraemia, and lead poisoning may all be relieved sometimes, and I have found an apparent cure follow an obscure case of headache. Babinski states he has sometimes relieved Menieres disease, and deafness with auditory vertigo. Purves Stewart reports relieving a case of tinnitus aurium. Optic neuritis can often be cured and

in other cases relieved. Thieberg and Ravant state they have found lumbar puncture extremely efficacious in pruritus. As a means for introducing anaesthetics to a localised area of the central nervous system it is rapidly gaining favour with surgeons, and similar means can be employed successfully to combat intense pain in the pelvic region and lower limbs produced by the pressure of neoplasms or other causes.

The value of the injection of bactericidal agents into the subarachnoid space is still in the experimental stage. I have lately used collargol by this method in the treatment of paralytic sequelae of ~~ser~~ebro-spinal meningitis. The reactionary symptoms were considerable, but the leucocytosis which followed was most uncertain, and less in subsequent injections than after the first. The value of the treatment seems questionable but deserves further investigation.

Conclusion.

These studies were commenced and developed at the Edinburgh City Hospital, and have since been matured by investigation in Continental Hospitals and at the Edinburgh Deaconess Hospital. My best thanks are due to Dr. Claude B. Ker and to Dr. Francis D. Boyd for the facilities they have so kindly afforded me of studying cases under their care.

References.

Quincke. Die lumbal ponction des Hydrocephalus. Berliner klinische Wochenschrift. xxviii, 929. 1891.. Die diagnostische und therapeutische Bedeutung der Lumbalpunktion. Klinische Med. Wochft. Oct. & Nov. 1905.

Skoezinsky. Chemische Untersuchung der Cerebro-spinalflüssigkeit, Sitzung der Berlin. Gesellschaft für Psych. u. Nerv. 1904.

Tuffier. L'Analgesie Chirurgicale par Voie rachidienne, L'Oeuvre Médico-Chirurgical No. 24. 1901.

Bier. Ueber Cocainisirung des Rückenmarks. Deutsche zeitschrift für Chirurgie, 1899, t. 11, p.361.

Juvara+Semain médicale, 1902, p.68.

Wells. Chemical Pathology. 1907.

Williamson- Lumbar Puncture. The Med-
Chronicle. 1906-7, xlv, 345-353.

Rons (F.P.) Am. J. Med. Scien. Phila. &
N.Y., 1907 u.s., cxxxiii, 567-582.

Pomeroy (J.L.). The Diagnostic value of
lumbar puncture in Psychiatry. J. of Nerv. &
Ment. Dis. Vol. 34, No. 4, 1907, p.225.

Stewart (Purves). E. Med. J. p. 429, 1906.

Warrington (W.B.) Brit. M.J. 1905, Vol. ii.,
p.1017.

Kaupe (W). Der diagnostische und thera-
peutische Wert der Spinalpunktion. Central-blatt
fur die Grenzgebiete der Medizin und Chirurgie,
p.801.

Gerhardt. Ueber die therapeutische und diagnos-
tische Bedeutung der Lunbalpunktion.

Grenzgeb f. Chir. u. Med. 1904

Discussion on lumbar puncture: its
diagnostic and therapeutic value. Brit. M.J.,
Lond., 1907, ii, 739-743.

Curschmann. La Semaine Médicale- 1907.
535.